

**Diaphragms made of cast polyarylate films**

The invention relates to diaphragms made of cast polyarylate films (cast PAR films), and in particular to their use as thermoformed microphone diaphragms or thermoformed loudspeaker diaphragms, and also to the corresponding cast PAR films, casting solutions for producing the cast PAR films, a process for producing thermoformed microphone diaphragms or thermoformed loudspeaker diaphragms, and a process for producing the PAR films.

Polymer films, inter alia composed of polycarbonates (PC), of polyesters (PET, PEN), of polyether sulfones (PES), and of polyetherimides (PEI) have hitherto been used for producing small diaphragms with a diameter of up to about 10 cm for acoustic applications (signal transducers) for use in mobile devices, such as microphones, mobile telephones, laptops, personal digital assistants (PDAs), or headphones, or as signal generators, e.g. in the automotive industry. In order to reduce the vibrating mass of the diaphragms, and to ensure precise reproduction of embossed structures during thermoforming, and to permit further miniaturization, the intention is that the films have minimum thickness. Films composed of the plastics mentioned have high mechanical strength, but have the disadvantage of generating a "metallic" sound when used as loudspeaker diaphragms, or of inadequate capability for deforming to reproduce relatively complicated embossed structures. Consequently, music signals and/or speech signals are altered disadvantageously on conversion into electrical signals and vice versa.

Small microphone diaphragms and small loudspeaker diaphragms are generally produced in the application sectors mentioned by the thermoforming process. This process heats the film for softening prior to the

thermoforming, for example through irradiation with infrared light (IR). The more anisotropic the film, the more difficult the control needed in industry for uniform heating and resultant uniform softening of particularly thin films prior to the thermoforming. Cast films are markedly more isotropic than stretched and/or extruded films. Films composed of extruded PC, polyethylene naphthalate (PEN), or polyethylene terephthalate (PET) tend to be deformed to a greater or lesser extent and/or to shrink, because some of the internal stress built up during the extrusion/stretching process is released during the heating process. Thin cast films have fewer internal stresses than extruded/stretched films and can be thermoformed more uniformly, and are particularly suitable for the application sectors mentioned. However, especially in the case of PET and PEN, the poor solubility of these polymers prevents the production of cast films.

It was an object of the invention to provide films for the production of diaphragms for acoustic applications. These diaphragms are moreover intended to permit good intelligibility of speech and high-quality reproduction of music at adequate volume, and to have high mechanical stability at a high temperature.

The high quality requirements, particularly applying to small diaphragms for acoustic applications, mean that even very thin films should permit uniform heating by IR and problem-free thermoforming.

In past years, diaphragms based on films have mainly been produced from extruded films. Only in the production of high-quality loudspeaker diaphragms has use also been made of cast films composed of polycarbonates.

Surprisingly, it has now been found that diaphragms made of cast PAR films have markedly better acoustic properties than diaphragms made, by way of example, of extruded PC films, of extruded PEN films, or of  
5 extruded PEI films. There are also marked advantages over cast PC films.

Cast PAR films are known to have very good properties of optical isotropy and high heat resistance, and have  
10 hitherto been used exclusively for optical applications (EP-A-0488221, JP-A-08/122526, JP-A-08/134336, and JP-A-08/269214).

When the strengths of many materials are determined,  
15 the measured values can be found to have a high degree of scatter, deriving from defects which are present in the material and whose distribution is a function of the production process. A reliable conclusion concerning the strength of a material, and therefore  
20 also relating to the distribution of defects within this material, requires knowledge not only of the average of the tensile stresses measured (maximum tensile stress, tensile stress at break), but also of the statistical distribution of the strength values. A  
25 proven statistical method is based on the extreme-value-distribution method of W. Weibull (Ing. Vetenskaps Akad. Handl., 151 (1939) 1-45), which calculates the probability that a specimen of given geometry will fail under a tensile stress  $\sigma$ . The two  
30 relevant tensile stress values, the maximum tensile stress, i.e. the tensile stress at which a steep fall-off in tensile stress begins, and therefore at which a steep fall-off in strength begins, and the tensile stress at break, i.e. the final tensile stress value  
35 measured prior to the complete separation of the material, correlate directly with the final failure of the material.

The improvement in the properties of maximum tensile stress and ultimate tensile strength of the inventive cast PAR film material, in comparison with cast PC films (PC-A and PC-B) composed of two different grades of polycarbonates could be demonstrated (see example 12) by studying 40 specimens of each.

It has also been found that cast PAR films have a high damping factor and have substantially linear acoustic properties over a wide range of frequencies and of volumes, and can therefore be utilized for acoustic applications. Diaphragms made of cast PAR films have excellent properties in relation to the initiation and attenuation of vibration, and uniform vibration behavior over a wide range of frequencies and of volumes, and permit good intelligibility of speech.

It has been found that colored cast PAR films can be very uniformly heated and thermoformed, and are therefore particularly well suited to the production of small diaphragms.

It has also been found that the addition of certain dyes or of nonionic surfactants has a favorable effect on undesirable thixotropic properties of the PAR casting solutions. The result is that the technical measures prior to and during the casting procedure can be simplified considerably, and the entirety of the casting process can be decisively improved.

Finished molded diaphragms made of PAR have increased heat resistance ( $T_g = 188^\circ\text{C}$ ) when compared with those made of PC ( $T_g = 135^\circ\text{C}$ ). The lower tendency toward shrinkage and dimensional stability at high temperature of diaphragms made of cast PAR films makes them superior to diaphragms made of extruded PC films, of extruded PEI films, of extruded PEN films, of extruded PES films, or of extruded PET films. When comparison is made with extruded and stretched films, for example PC

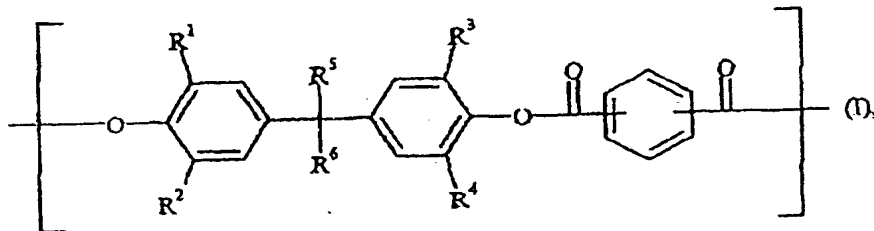
films, PEI films, or PEN films, diaphragms with more complicated geometries can be produced from PAR films.

5 Because they are highly isotropic, cast PAR films are preferably used in the form of unstretched films for diaphragm production. However, the inventive cast PAR films may, where appropriate, be mono- or biaxially stretched prior to diaphragm production.

10 Diaphragms produced from PAR moreover have low flammability, even without additives which may affect vibration performance.

15 It has also been found that diaphragms made of PAR films have increased moisture resistance.

20 According to claim 1, thermoformed diaphragms for acoustic applications are produced from cast PAR films which comprise at least one polyarylate having a structural unit of the formula



25 where each of  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$ , independently of the others, is hydrogen,  $C_{1-4}$ -alkyl,  $C_{1-4}$ -alkoxy, or halogen, and each of  $R^5$  and  $R^6$ , independently of the other, is hydrogen,  $C_{1-4}$ -alkyl,  $C_{1-4}$ -alkoxy, phenyl, or halogen.

30 In one preferred embodiment,  $R^1 = R^2$  and  $R^3 = R^4$  and each, independently of the others, is hydrogen or  $C_{1-4}$ -alkyl.

In a particularly preferred embodiment,  $R^1 = R^2 = R^3 = R^4$ , and are each hydrogen or  $C_{1-4}$ -alkyl.

In another preferred embodiment each of,  $R^5$  and  $R^6$ , independently of the other, is  $C_{1-4}$ -alkyl. In one particularly preferred embodiment,  $R_5 = R_6 = \text{methyl}$ .

5 By way of example, polyarylate where  $R^1 = R^2 = R^3 = R^4 =$   
hydrogen and  $R^5 = R^6 = \text{methyl}$  and where the molecular  
weight is in the range from 10 000 to 150 000 may be  
purchased from UNITIKA CHEMICAL K.K., 3-11, Chikkoshin-  
machi, Sakai-shi, Osaka 592, Japan with the name  
10 "U-Polymer 100".

The inventive diaphragms may have a thickness of from 5  
to 200  $\mu\text{m}$ , preferably from 5 to 100  $\mu\text{m}$ , and  
particularly preferably from 10 to 50  $\mu\text{m}$ .

15 According to the invention, the excellent damping  
properties (internal loss) of PAR films makes them  
particularly well suited to the production of  
thermoformed diaphragms as acoustic transducers for  
20 acoustic applications, preferably as microphone  
diaphragms and/or loudspeaker diaphragms. When compared  
with known diaphragms composed of other polymers, they  
have less "metallic" sound characteristics.

25 The mechanical strength of the inventive PAR diaphragms  
is markedly better than that of PC diaphragms, and  
gives a longer lifetime when electrically driven, using  
the same nominal power rating, at an elevated  
temperature.

30 The inventive thermoformed PAR diaphragms are  
particularly suitable when requirements for  
intelligibility of speech are high, for example in use  
as diaphragms for the microphones or loudspeakers in  
35 microphone capsules, in mobile telephones, in hands-  
free systems, in radiosets, in hearing devices, in  
headphones, in microradios, in computers, and in PDAs.  
Another application sector is the use as a signal  
generator.

All of the % data below for amounts of dyes and surfactants are percentages by weight, based on the solids content in the PAR casting solutions and/or of  
5 cast PAR films produced therefrom.

All of the % data below for amounts of polyarylate are percentages by weight, based on the total weight.

10 For the production of inventive diaphragms made of cast PAR films as claimed in claim 1, for example by means of thermoforming, the films are irradiated with infrared light (IR) to improved deformability, and are heated thereby. The addition of a dye has proven  
15 advantageous here, because this achieves uniform heat absorption and softening. The result is that the inventive cast PAR films can be processed more effectively, and the quality of the diaphragms produced therefrom is improved.

20 Amounts as small as 0.01% of a commercially available dye, such as "C.I. Solvent Yellow 93" or "Macrolex® Orange R" are sufficient for uniform heating of inventive cast PAR films. The amount of dye may be  
25 still further reduced is use is made of pure pigments without auxiliaries and/or fillers.

By way of example, the dye "C.I. Solvent Yellow 93" is obtainable from BAYER, Germany with the trade name  
30 Transparent Yellow 3G", from KUNSHAN FAR EAST CHEMICAL COMPANY Ltd., South of Bingxi Town, Kunshan, Jiangsu 215334, PR China, from CHINA CHEMICALS, Luxun Mansion 12 Fl./Suite G, 568 Ou Yang Road, Shanghai 200081, PR China, and also from HONGMENT CHEMICALS LIMITED,  
35 Xinzhuhuayuan 32-203, Ningxi Road, Zhuhai, PR China.

A dye equivalent to "C.I. Solvent Yellow 93", "BASF Thermoplast Yellow 104", is obtainable from BASF, Germany, or with the name "Solvent Yellow 202" from

ZHUHAI SKYHIGH CHEMICALS Co., Ltd., 20/F, Everbright International Trade Centre, Zhuhai City, Guangdong Province, PR China.

- 5 By way of example, "Macrolex® Orange R" may be purchased from BAYER, Germany.

10 The currently obtainable commercial forms of the dyes mentioned comprise, inter alia, nonionic polyol surfactants, the advantageous effects of which on inventive PAR casting solutions are described at a later stage below.

15 Inventive PAR casting solutions and/or cast PAR films produced therefrom comprise at least one of the dyes mentioned and/or one non-ionic polyol surfactant.

20 Nonionic polyol surfactants are generally nonionic water-soluble polyoxyalkylenes, such as poly(ethylene oxide) or poly(ethylene glycol) (PEO), poly(propylene oxide), or poly(propylene glycol) (PPO), or poly(tetramethylene oxide) (PTMO), having the structural unit  $-[(CH_2)_x-CHR-O]-$  as a common feature, where (i) R may be H, x may be 1 (poly(ethylene glycol), (PEO)); (ii) R may be  $CH_3$ , x may be 1 (poly(propylene glycol), (PPO)); or (iii) R may be H, x may be 3 (poly(tetramethylene oxide), (PTMO)). Polyol surfactants are not only PEO homopolymers, PPO homopolymers, and PTMO homopolymers, but also  
30 copolymers of these, in particular block copolymers, and/or polymer mixtures thereof, with an average molecular weight below 20 000.

35 An example of commercially available poly(ethylene glycol)-poly(propylene glycol) block copolymers is "Pluronic® PE 6800" from BASF or "Synperonic® F86 pract." from SERVA.



Casting solutions composed of PAR of the formula (I) in methylene chloride, where each of  $R^1$ ,  $R^2$ ,  $R^3$ , and  $R^4$ , independently of the others, is hydrogen,  $C_{1-4}$ -alkyl,  $C_{1-4}$ -alkoxy, or halogen, and where each of  $R_5$  and  $R_6$ ,  
5 independently of the other, is hydrogen,  $C_{1-4}$ -alkyl,  $C_{1-4}$ -alkoxy, phenyl, or halogen, are highly thixotropic, and cannot be stored in the form of ready-to-use solutions without motion. In order to prevent the casting solutions from solidifying in the manner of a  
10 gel in the storage containers, in the conveying system, in the filters, or in the casting apparatus, it is necessary to take comprehensive precautions to ensure continuous motion and to avoid "dead spots".

15 Surprisingly, it has been found that a dye such as "C.I. Solvent Yellow 93", "Solvent Yellow 202", or "Macrolex® Orange R" acts as an agent with anti-thixotropic properties when added to the PAR casting solutions.

20 Further tests have shown that nonionic polyol surfactants, such as poly(ethylene glycol)-poly(propylene glycol) block copolymers, also bring about this effect when used alone. PAR casting  
25 solutions to which one of the nonionic polyol surfactants and/or dyes mentioned is added lose their thixotropic properties. This considerably simplifies the casting process, and the inventive ready-to-use PAR casting solutions can be stored for some weeks. In  
30 contrast, PAR casting solutions with no addition of surfactant and/or of colorant lose their usefulness completely after as little as a few hours if stored without motion (see example 11).

35 The nonionic polyol surfactants and dyes mentioned may comprise other additives, such as  $TiO_2$ .

Inventive PAR casting solutions and/or cast PAR films produced therefrom comprise a dye and/or a non-ionic polyol surfactant.

- 5 In one particular embodiment, inventive PAR casting solutions and/or cast PAR films produced therefrom comprise at least one nonionic surfactant, selected from the group consisting of poly(ethylene glycol) poly(propylene glycol), and poly(tetramethylene oxide),  
10 where the surfactants mentioned may be used in the form of homopolymers, copolymers, or block copolymers, individually or in the form of a mixture.

- In one particularly preferred embodiment, inventive PAR  
15 casting solutions and/or cast PAR films produced therefrom comprise at least one polyethylene-polypropylene block copolymer with an average molecular weight of from 6 000 to 10 000.

- 20 In one particularly preferred embodiment, inventive PAR casting solutions and/or cast PAR films produced therefrom comprise a dye, such as "C.I. Solvent Yellow 93", "Solvent Yellow 202", or "Macrolex® Orange R", and/or comprise a nonionic polyol surfactant, such as  
25 "Pluronic® PE 6 800" or "Synperonic® F86 pract."

- Inventive PAR casting solutions and/or cast PAR films produced therefrom comprise PAR of the formula (I) as claimed in claim 1, and also comprise a dye and/or a  
30 nonionic polyol surfactant in an amount of from 0.001 to 2%, preferably in an amount of from 0.001 to 0.15%.

- The dye and/or the non-ionic polyol surfactant may be dissolved, by way of example, in acetone, butyl  
35 acetate, or methylene chloride, particularly preferably in methylene chloride.

In one preferred embodiment, the dye, such as "C.I. Solvent Yellow 93", "Solvent Yellow 202", or "Macrolex®

Orange R" itself comprises a nonionic polyol surfactant, such as "Pluronic® PE 6 800" or "Synperonic® F86 pract.", and may be dissolved in the from of a mixture therewith.

- 5 The form in which the dye and/or the non-ionic polyol surfactant is metered into the PAR casting solution until the desired amount has been reached is preferably that of a solution in methylene chloride.
- 10 In another preferred embodiment, the dye and/or the non-ionic polyol surfactant is pre-dissolved in the methylene chloride used as solvent for the preparation of the PAR casting solution.
- 15 Suitable concentrations for the inventive PAR casting solutions in methylene chloride extend from 10% to the limit of solubility. They are preferably in the range from 15 to 25%, particularly preferably in the range from 20 to 24%.
- 20 In one method of producing the diaphragms, the heated and softened PAR films are deformed by means of thermoforming in a thermoforming mold. By way of example, this may be achieved by applying air pressure or a vacuum, or using a mechanical ram. The thermo-  
25 forming processes may also be used in combination with one another.
- The preferred method for the heating procedure is  
30 irradiation with infrared light.
- The finished molded diaphragms may then be cut out from the film by means of a mechanical process, for example using a knife or a stamp, or by a contactless method,  
35 for example with the aid of a water jet or of a laser. The molded diaphragms are preferably stamped out or laser-cut.

The outer periphery of the diaphragms may then be bonded to a support ring composed of plastic or metal and to a coil with connecting contacts, and installed as a microphone diaphragm or loudspeaker diaphragm together with a permanent magnet into appropriate apparatus acting as a transducer or generator of acoustic signals.

To produce cast polyarylate films, the inventive polyarylate casting solutions are applied by means of a suitable casting device to a substrate, peeled away from this substrate after a period of predrying, and then dried fully.

In one particular embodiment, the cast film is applied by means of a suitable casting device or doctor blade to a glass substrate, predried, peeled away, and finally dried to the desired residual solvent concentration.

In another preferred embodiment, the cast film is applied by means of a suitable casting device to a continuous substrate, predried, peeled away, and finally dried to the desired residual solvent concentration.

In another preferred embodiment, the continuous substrate is a steel belt which is matt or polished on one side and has a length of from 20 to 100 m, or a polished or matt stainless steel roll of circumference from 5 to 25 m.

Particularly in the case of very thin films with film thicknesses  $< 20 \mu\text{m}$ , it can be advantageous, for increasing the stability of the inventive cast films and for avoiding strain due to tensile stress during the further processing of these films, not to apply the cast film directly to one of the substrates mentioned, but to apply it to an intermediate film which is

conducted on the actual substrate. After the predrying period described, this intermediate film may then be peeled away together with the cast film from the actual substrate, and the cast film may be subjected to final drying as described. It is of little importance here whether and when the inventive cast film is separated from the intermediate film. The intermediate film is preferably wound onto rolls together with the inventive cast film and then further processed.

10 In one preferred embodiment, the intermediate film used comprises a polymer film, particularly preferably a PET film.

15 In one preferred embodiment, the predrying process preceding the peeling-away of the preformed film takes place directly through infrared irradiation or microwave irradiation, or electrical heating, or indirectly through contact with hot air.

20 In one preferred embodiment, the solvent content of the PAR film after peeling-away is from 5 to 15%. In another preferred embodiment, the final drying to the desired residual solvent concentration takes place in a  
25 heatable drying cabinet through direct and/or indirect heating. The material is particularly preferably unsupported during final drying.

The method of heating may be direct, through infrared  
30 and/or microwave heating, and/or indirect, through contact with air at a controlled temperature.

In one preferred embodiment, the PAR film is transported at a speed of from 1 to 20 m/min, preferably from 2 to 5 m/min. During this process, the  
35 final drying may be carried out at a temperature in the range from 50 to 200°C. The average thickness of the inventive PAR film after the final drying process is from 5 to 200 µm, its solvent content being below 1.5%.

The properties of the inventive cast PAR films may be still further optimized through coatings. By way of example, these coatings may be applied from a solution or take the form of a laminated-on film or laminated-on layer. In another embodiment, these coatings may also be achieved by extrusion coating, because the PAR film has high heat resistance. By way of example, the coating may further improve the damping properties.

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Examples of methods of solution coating are roller application, doctor-blade application, or spray application. Examples of suitable solutions for solution coating are solutions of polyurethanes (PUs) or of acrylates in suitable solvents. Films composed of PE, PP or PU are suitable for lamination-coating. For lamination, use may be made of unstretched or mono- or biaxially stretched cast films, or of extruded films, by a method which brings about lasting and adequately high adhesion between the individual layers, for example by means of an additional application of adhesive (adhesive lamination) or true lamination through application of pressure and heat.

After the drying process, and, where appropriate, after a further coating process and, where appropriate, after pre-finishing, for example through roll cutting, the inventive cast PAR film may, as described above, be further processed in a thermoforming apparatus to give diaphragms.

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#### **Examples**

Although complete disclosure of the working of the present invention is provided by the inventive examples 1-13 given, the claimed variations in the process parameters also make it possible to carry out numerous other inventive examples. Examples which are carried out by implementing these variations defined within the Description and within the claims are intended to be

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regarded as inventive examples and to fall within the scope of protection of this patent application.

**Example 1**

- 5 The production batch size was 600 kg of "U-Polymer 100" polyarylate from UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 =$  methyl, which were weighed out into 2 062 kg of methylene chloride and dissolved during the course of 3 h at room  
10 temperature and a further 3 h at 39°C with continuous stirring. 300 g of "C.I. Solvent Yellow 93" dye from BAYER were added in the form of powder during stirring of the mixture. The solids content of the lacquer was 22.5%.
- 15 The lacquer was used to produce films of thickness 100 µm and width about 110 cm.

**Example 2**

- The production batch size was 600 kg of "U-Polymer 100" polyarylate from UNITIKA, having the formula (I), where  
20  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 =$  methyl, which were weighed out into 2 062 kg of methylene chloride and dissolved during the course of 3 h at room temperature and a further 3 h at 39°C with continuous  
25 stirring. 300 g of "Macrolex® Orange R" dye from BAYER were added in the form of powder during stirring of the mixture. The solids content of the lacquer was 22.5%. The lacquer was used to produce films of thickness 100 µm and width about 110 cm.

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**Example 3**

- The production batch size was 300 kg of "U-Polymer 100" polyarylate from UNITIKA, having the formula (I), where  
35  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 =$  methyl, which were weighed out into 1 100 kg of methylene chloride and dissolved during the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. 32 g of "C.I. Solvent Yellow 93" dye from BAYER were added in the form of powder during stirring

of the mixture. The solids content of the lacquer was 21.5%.

The lacquer was used to produce films of thickness 20, 25, 30, 40, 60, 80, and 100  $\mu\text{m}$ , and width of from about  
5 110 to 120 cm.

#### Example 4

For products cast by a manual process, from 0.3 to 2.0 kg of lacquers with from 15 to 24% polymer content  
10 were prepared by dissolving "U-Polymer 100" PAR from UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 =$  methyl, in methylene chloride over the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. The  
15 lacquers for products cast by a manual process comprised 0.01% content of "C.I. Solvent Yellow 93" dye. The lacquers were used to produce products cast by a manual process in DIN A4 format, the film thickness being from 15 to 100  $\mu\text{m}$ .

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#### Example 5

For products cast by a manual process, from 0.3 to 2.0 kg of lacquers with from 15 to 24% polymer content were prepared by dissolving "U-Polymer 100" PAR from  
25 UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 =$  methyl, in methylene chloride over the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. The lacquers for products cast by a manual process  
30 comprised 0.01% content of "Macrolex® Orange R" dye. The lacquers were used to produce products cast by a manual process in DIN A4 format, the film thickness being from 15 to 100  $\mu\text{m}$ .

#### 35 Example 6

For products cast by a manual process, from 0.3 to 2.0 kg of lacquers with from 15 to 24% polymer content were prepared by dissolving "U-Polymer 100" PAR from UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$



hydrogen and  $R^5 = R^6 = \text{methyl}$ , in methylene chloride over the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. The lacquers for products cast by a manual process  
5 comprised 0.01% content of "Pluronic® PE 6800" surfactant. The lacquers were used to produce products cast by a manual process in DIN A4 format, the film thickness being from 15 to 100 µm.

10 **Example 7**

For products cast by a manual process, from 0.3 to 2.0 kg of lacquers with from 15 to 24% polymer content were prepared by dissolving "U-Polymer 100" PAR from UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$   
15 hydrogen and  $R^5 = R^6 = \text{methyl}$ , in methylene chloride over the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. The lacquers for products cast by a manual process comprised 0.001% content of "C.I. Solvent Yellow 93"  
20 dye. The lacquers were used to produce products cast by a manual process in DIN A4 format, the film thickness being from 15 to 100 µm.

**Example 8**

25 For products cast by a manual process, from 0.3 to 2.0 kg of lacquers with from 15 to 24% polymer content were prepared by dissolving "U-Polymer 100" PAR from UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 = \text{methyl}$ , in methylene chloride  
30 over the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. The lacquers for products cast by a manual process comprised 0.001% content of "Macrolex® Orange R" dye. The lacquers were used to produce products cast by a  
35 manual process in DIN A4 format, the film thickness being from 15 to 100 µm.

**Example 9**

For products cast by a manual process, from 0.3 to 2.0 kg of lacquers with from 15 to 24% polymer content were prepared by dissolving "U-Polymer 100" PAR from UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 =$  methyl, in methylene chloride over the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. The lacquers for products cast by a manual process comprised 0.001% content of "Pluronic® PE 6800" surfactant. The lacquers were used to produce products cast by a manual process in DIN A4 format, the film thickness being from 15 to 100 µm.

#### Comparative example 10

For products cast by a manual process, from 0.3 to 2.0 kg of lacquers with from 15 to 24% polymer content were prepared by dissolving "U-Polymer 100" PAR from UNITIKA, having the formula (I), where  $R^1 = R^2 = R^3 = R^4 =$  hydrogen and  $R^5 = R^6 =$  methyl, in methylene chloride over the course of 3 h at room temperature and a further 3 h at 39°C with continuous stirring. No dye and/or surfactant content was present in the lacquers for products cast by a manual process. The lacquers were used to produce products cast by a manual process in DIN A4 format, the film thickness being from 15 to 100 µm.

#### Example 11

The thixotropic behavior of lacquer specimens from the lacquers from examples 1 to 9, and also from comparative example 10, was observed at particular times after preparation of the ready-to-use solutions. For this, specimens of each of the lacquers were transferred into 5 different vessels. After 30 min, 4 h, 8 h, 20 h, and after from 1 to 4 weeks, films were produced, where possible, by a manual casting process. The observations are given in table 1.

Table 1

Lacquer	after 30 min	after 4 h	after 8 h	after 20 h	after 4 weeks
Example 1	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening
Example 2	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening
Example 3	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening	useful stable solution with no thickening
Examples 4-6	useful stable solutions with no thickening	useful stable solution with no thickening	useful stable solutions with no thickening	useful stable solutions with no thickening	useful stable solutions with no thickening
Examples 7-9	useful stable solutions with no thickening	useful stable solution with no thickening	useful stable solutions with no thickening	useful stable solutions with no thickening	useful stable solutions with no thickening
Comparative example 10	incipient thickening	sharp viscosity rise	solution is gel-like and has become unusable	solid gel, no residual motion discernible on inversion	solid gel, no residual motion discernible on inversion

### Example 12

Tensile stress at break and maximum tensile stress were in each case evaluated for 40 film specimens of thickness 30  $\mu\text{m}$  composed of 3 different materials (PC-B, PAR, PC-A) using the Weibull method.

The characteristic Weibull statistical parameters are summarised in table 2. The specimen termed PAR represents an inventive cast PAR film. PC-A and PC-B represent specimens of cast polycarbonate films. PC-A is the current standard polycarbonate for loudspeaker diaphragms made of cast PC films. PC-B is composed of a comparative PC material which was tested as alternative to PC-A.

Table 2

Polymer	N	Tensile stress at break				Maximum tensile stress			
		$\bar{\sigma} \pm \Delta\sigma$ [MPa]	$\sigma_{c,0}$ [MPa]	$\sigma_m$ [MPa]	$m$	$\bar{\sigma} \pm \Delta\sigma$ [MPa]	$\sigma_{c,0}$	$\sigma_m$ [MPa]	$m$
PC-B	40	$24.9 \pm 5.8$	27.3	25.2	4.6	$73.5 \pm 3.5$	75.1	74.0	24.9
PAR	40	$30.9 \pm 5.7$	33.3	31.3	6.0	$77.3 \pm 3.4$	78.8	77.8	28.3
PC-A	40	$42.9 \pm 8.7$	46.6	43.5	5.3	$85.1 \pm 6.1$	87.8	85.9	16.8

N: Number of specimens

$\bar{\sigma} \pm \Delta\sigma$ : Arithmetic average with standard deviation

$\sigma_{c,0}$ : Characteristic strength (probability of break 63.2%)

$\sigma_m$ : Median strength (probability of break 50%)

$m$ : Weibull modulus

The Weibull moduli  $m$ , which characterize the homogeneity of the materials, have the following order for the maximum tensile stress and the tensile stress at break, rising  $m$  indicating increasing homogeneity and less scatter of measured values.

Maximum tensile stress:  $m$  (PC-A) <  $m$  (PC-B) <  $m$  (PAR)

Tensile stress at break:  $m$  (PC-B) <  $m$  (PC-A) <  $m$  (PAR)

When compared with two different cast PC films, the inventive cast PAR film has the lowest inhomogeneity values

and, together with this, also the narrowest distribution of measured values.

**Example 13**

5 Lifetime test comparison of standard and high-performance  
types of loudspeaker composed of cast PAR film and cast PC  
film (PC-A and PC-B, see example 12), based on  
DIN ETS 300019 "Geräte-Entwicklung; Umweltbedingungen und  
10 Umweltprüfungen für Telekommunikationsanlagen" [Equipment  
development; environmental conditions and environmental  
tests for telecommunications equipment]. PAR represents the  
inventive cast PAR film. 5 different loudspeaker types were  
tested, in each case using at least 50 loudspeakers per  
type and diaphragm diameter. The loudspeakers were  
15 subjected to various tests, such as repeated passage  
through temperature cycles (from -40 to 85°C) at high  
humidity, or prolonged exposure to 85°C. Each loudspeaker  
was tested for the total period of 500 h under an  
electrical load, using "pink noise" at the respective power  
20 rating given in the data sheet for the respective  
loudspeaker. The results given are restricted to  
qualitative assessments, because the failures occur at  
varying times within the test. Table 5 gives the  
assessments and states whether the number of loudspeakers  
25 tested differs significantly from the number of  
loudspeakers remaining functional after the test.  
Loudspeaker diaphragms made of the inventive cast PAR film  
come out of the lifetime test at least as well as the  
current standard material.

30

**Table 3**

Example	Diaphragm diameter	Film thickness	Number of types	PC-B	PC-A	PAR
13-1	13 mm	30 $\mu$ m	4	-	+	+
13-2	16 mm	40-60 $\mu$ m	3	-	+	+
13-3	13 mm	30-60 $\mu$ m	8	-	+	+
13-4	23-38 mm	40-150 $\mu$ m	24	+	(+)	(+)
13-5	28 mm	100 $\mu$ m	1	-	(+)	+

+ = Lifetime test passed with minimal losses, (+) =  
lifetime test passed with reservations, with losses  
5 remaining acceptable, - = lifetime test not passed  
because of high losses